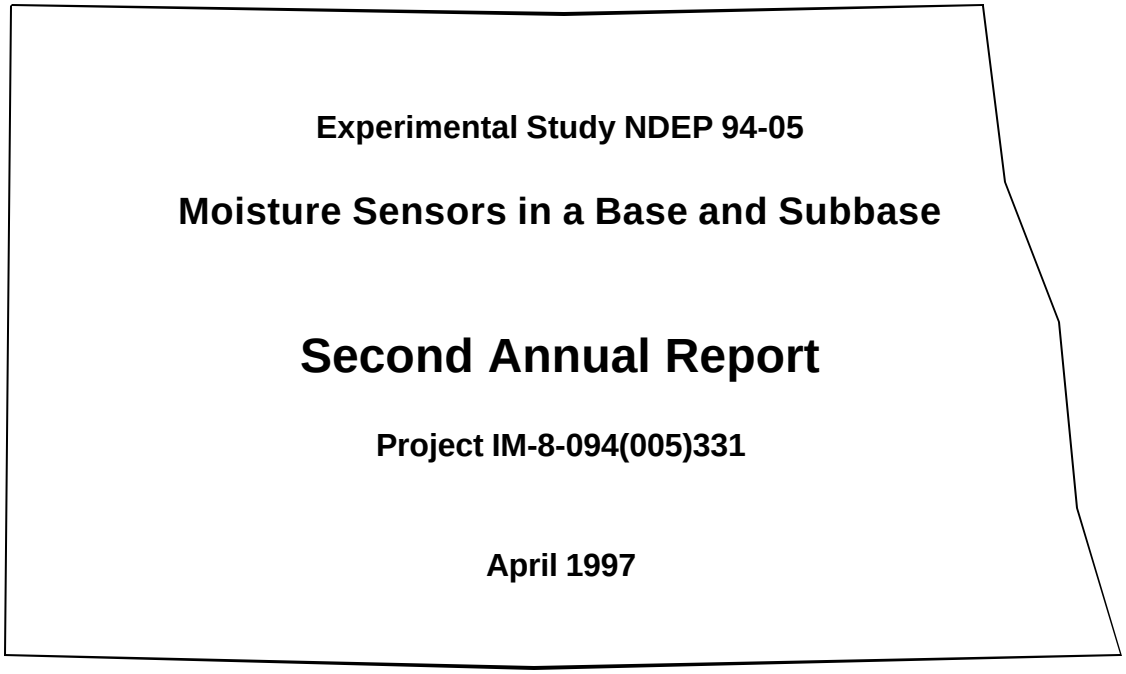
NORTH DAKOTA
DEPARTMENT OF TRANSPORTATION

MATERIALS AND RESEARCH DIVISION



Experimental Study NDEP 94-05

Moisture Sensors in a Base and Subbase

Second Annual Report

Project IM-8-094(005)331

April 1997

Prepared by

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION
BISMARCK, NORTH DAKOTA
Website: http://www.discovernd.com/dot/

DIRECTOR
Marshall W. Moore

MATERIALS AND RESEARCH DIVISION
Ron Horner

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

EXPERIMENTAL PROJECT REPORT

EXPERIMENTAL PROJECT

EXPERIMENTAL PROJECT NO.

	STATE	YEAR		NUMBER	SURF
1	ND	94	-	05	

CONSTRUCTION PROJ NO: 8 IM-8-094(005)331

LOCATION: 2 Cass County

EVALUATION FUNDING

1 HP&R
2 CONSTRUCTION
3 DEMONSTRATION
4 IMPLEMENTATION

48

NEEP NO.: 49

PROPRIETARY FEATURE?: 51 No

SHORT TITLE

TITLE 52: Moisture Sensors in a Base and Subbase

THIS FORM

DATE 140: MO. 0 4 - YR. 9 7

REPORTING: 1 INITIAL 2 X ANNUAL 3 FINAL

KEY WORDS

KEY WORD 1:

KEY WORD 2:

KEY WORD 3:

KEY WORD 4:

UNIQUE WORD:

PROPRIETARY FEATURE NAME:

CHRONOLOGY

Date Work Plan Approved	Date Feature Constructed:	Evaluation Scheduled Until:	Evaluation Extended Until:	Date Evaluation Terminated:
04-94	09-94	08-99		
277	281	285	289	293

QUANTITY AND COST

QUANTITY OF UNITS: 297

UNITS: 305

1 LIN. FT
2 SY
3 SY-IN
4 CY
5 TON
6 LBS
7 EACH
8 X LUMP SUM

UNIT COST (*Dollars, Cents*): 25579.20 — 306

AVAILABLE EVALUATION REPORTS

315

X CONSTRUCTION | X PERFORMANCE | FINAL

EVALUATION

CONSTRUCTION PROBLEMS		PERFORMANCE	
1 X	NONE	1	EXCELLENT
2	SLIGHT	2	GOOD
3	MODERATE	3	SATISFACTORY
4	SIGNIFICANT	4	MARGINAL

APPLICATION

1 ADOPTED AS PRIMARY STD.
2 PERMITTED ALTERNATIVE
4 PENDING
5 REJECTED

(Explain in remarks if 3, 4, 5, or 6 is checked)

REMARKS

321 Results inconclusive. It appears that at joint locations the drainable base is not effective or is only marginally effective in reducing the moisture content of the subgrade at the joint locations. The mid-panel locations appear to show the dense graded base is more effective than the drainable base, however, the moisture content in the subgrade shows the drainable base to be more effective.

700

Form FHWA 1461

EXPERIMENTAL

Moisture Sensors in a Base and Subbase

SECOND ANNUAL REPORT

IM-8-094(005)331

MARCH 1997

Written by
Jeff M. Richter

Disclaimer

The contents of this report reflect the views of the author or authors who are responsible for the facts and the accuracy of the data presented herein. The contents do not reflect the official views of the North Dakota Department of Transportation or the Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

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Graph 4 Moisture %'s in base under Mid-Panel 1996 8

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SUMMARY 11-14

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Figure 6 Average Moisture Dense Graded Base @ Joint 12

Figure 7 Average Moisture Drainable Base @ Mid-Panel 13

Figure 8 Average Moisture Dense Graded Base @ Mid-Panel 13

APPENDIX A: . . . . . Construction Plans

MOISTURE SENSORS IN A BASE AND SUBBASE

Project IM-8-094(005)331
NDEP94-05

PURPOSE:

The purpose of this study is to determine the effectiveness of a permeable base in reducing the moisture levels in the base and subgrade.

SCOPE:

The scope of this experimental project is to compare the moisture levels in the salvaged base beneath a permeable base, in a dense graded base, and in the subgrade. These sections are beneath a Portland Cement Concrete (PCC) pavement roadway surface.

LOCATION:

This project is located in the eastbound lanes of Interstate 94 in Cass County near Casselton, North Dakota. The moisture sensors are located at station 880+98.4, station 881+35.9, station 891+52.5, and station 891+90. See appendix A.

DESIGN:

The design called for placing three moisture sensors in two different roadway sections. The first section consists of four inches of a drainable base and eight inches of salvaged bituminous base placed on the subgrade as shown in figure 1.

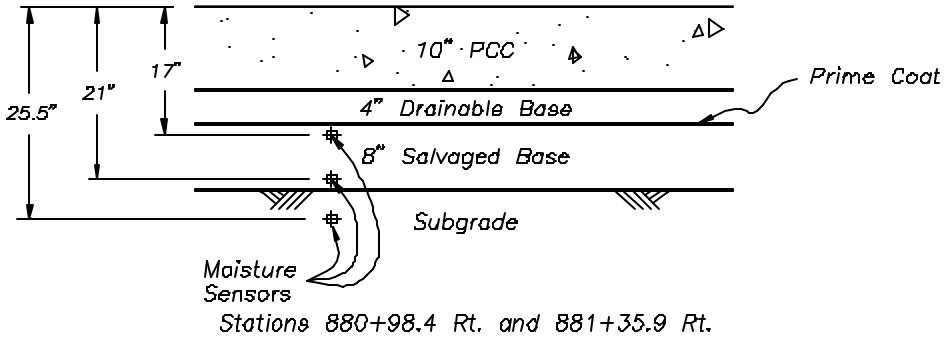
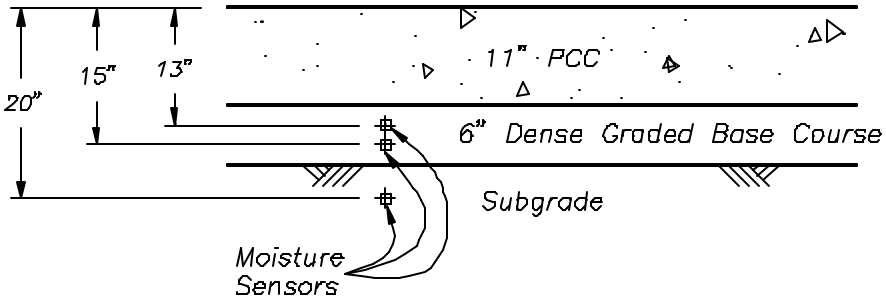


Figure 1

The second section consists of six inches of dense graded base placed on the subgrade as shown in figure 2 below. Each section called for placement of moisture sensors at two locations. The roadway section with a drainable base called for placing two moisture sensors in the salvaged base and one sensor in the subgrade as shown in figure 1. The roadway section without the permeable base called for placing two moisture sensors in the dense graded base and one sensor in the subgrade as shown in figure 2.



Stations: 891+52.5 Rt. and 891+90 Rt.

Figure 2

The sensors were located below a skewed transverse joint and below the midpoint of a concrete panel for each type of base course as shown in figures 3 and 4.

It is anticipated that the joint sealant will eventually lose its sealing capacity and allow moisture to readily enter the base material below the joints. It is then anticipated that the permeable base will remove the excess moisture while the dense graded base will allow the moisture to accumulate causing the base to lose its support capability.

The amount of moisture entering the base course at the midpoint of the PCC panels will be dependent on the lateral movement of the moisture in the base and capillary movement of moisture from the subgrade.

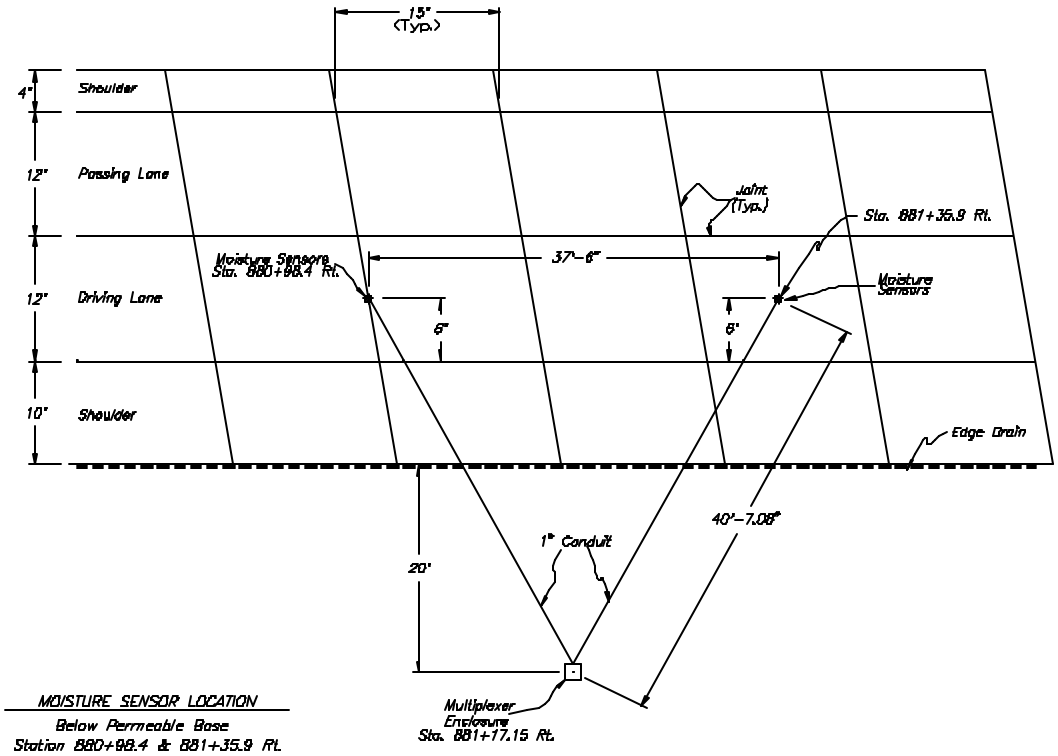


Figure 3

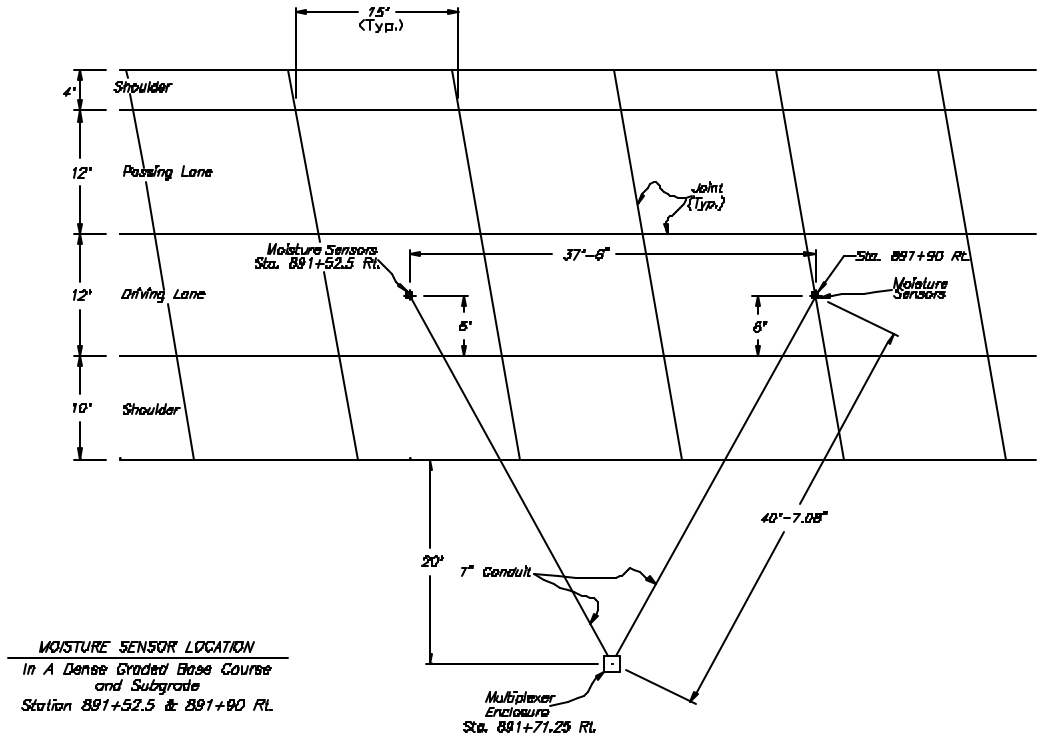


Figure 4

CONSTRUCTION:

Installation of the moisture sensors was performed by Fargo Electric from Fargo, North Dakota in September 1994. The installation was constructed to plan without problem in the following sequence:

1) **Installation of cabinet concrete footings**
2) **Trenching for conduit and sensors**
3) **Installation of sensors and conduit**
4) **Compaction of trench fill**
5) **Mounting of controlled environment cabinets**
6) **Installation of multiplexer control panel**
7) **Tagging and recording cables from sensors**

EVALUATION:

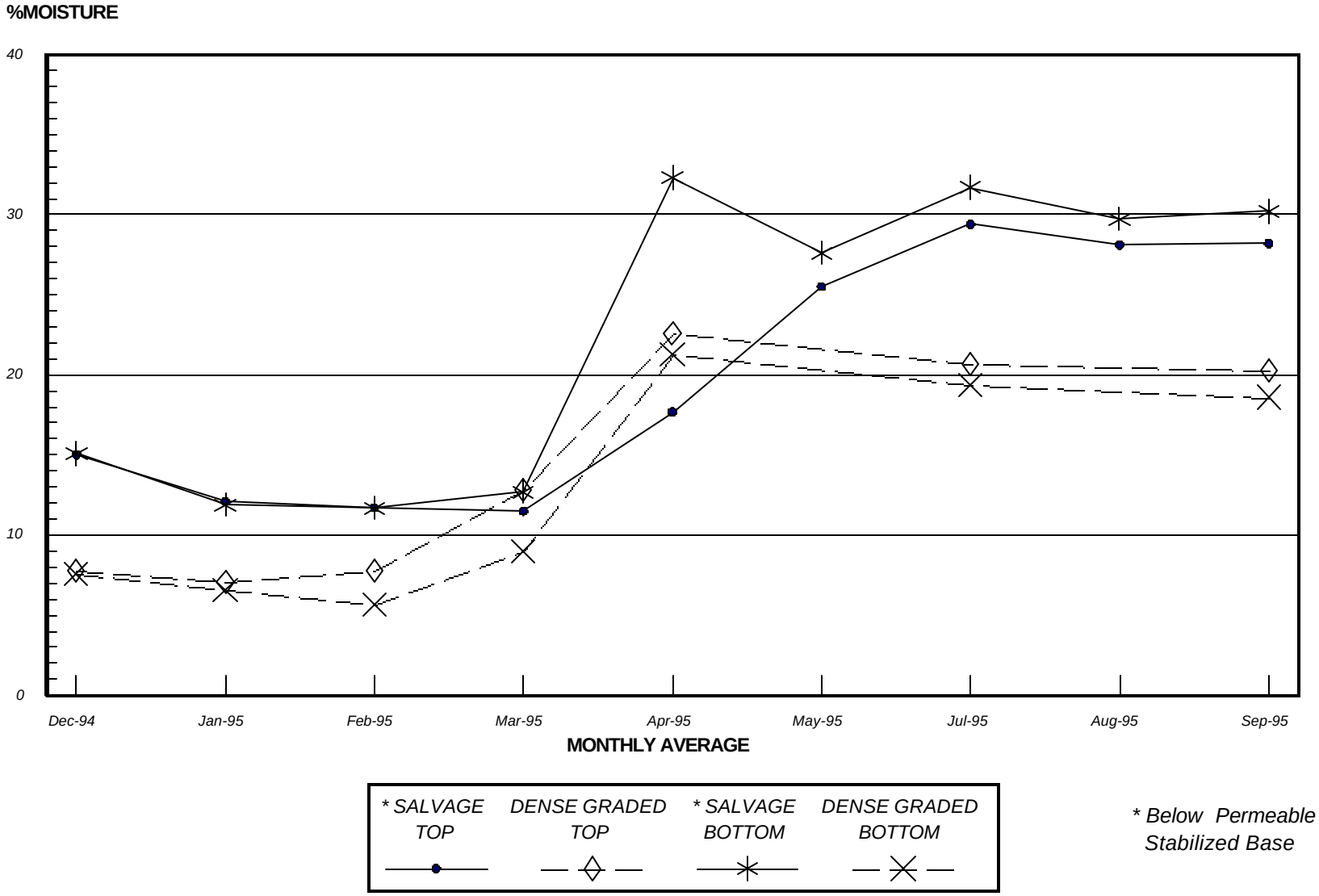
The graphs on the following pages represent the monthly average of the data collected from the moisture sensors. Graph 1 and Graph 2 include data from the sensors in the salvaged base and in the dense graded base located at the transverse joints. Graph 3 and Graph 4 include data from the sensors in the salvaged base and in the dense graded base located at the midpoint of the PCC pavement panels. Graph 5 and Graph 6 represent data from the sensors located in the subgrade for all locations.

There is no data available for the month of June 1995 for any of the sensors. There was erroneous data from the sensors in the subgrade under the mid-panel dense graded base during May, July, August, and September of 1995, which was not included in graph 5. There was also erroneous data from the sensors in the subgrade under the transverse joint dense graded base during May and August of 1995 which was not included in graph 5. The data for 1996 includes only the months of April, May, June, and July. This is due to problems collecting the data between January and April of 1996. It was also decided to change the evaluation parameters of the study to include data from July to July for the next comparisons.

SENSORS LOCATED AT TRANSVERSE JOINT

WITHIN BASE COURSE

1995



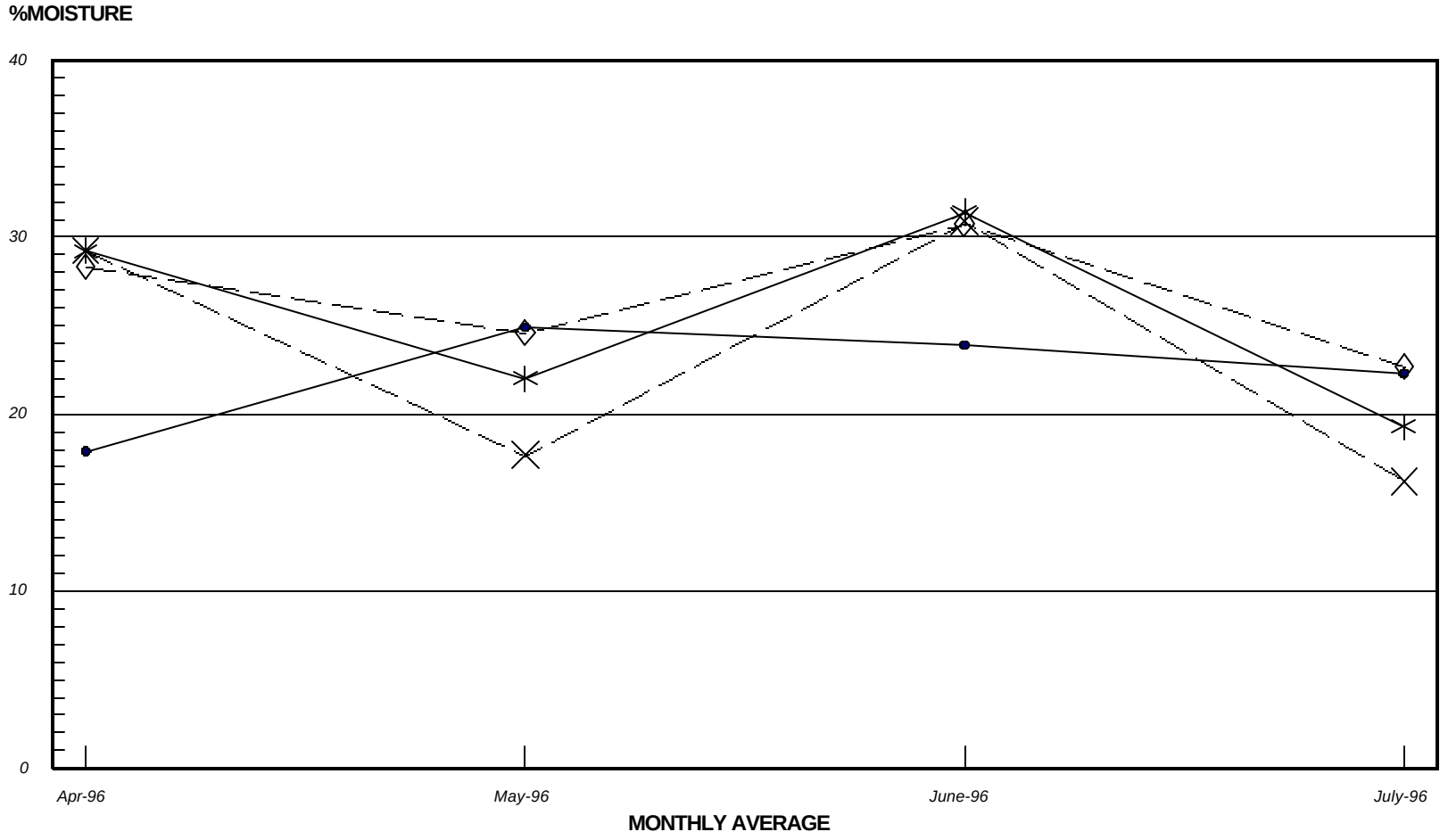
** Below Permeable Stabilized Base*

Graph 1

SENSORS LOCATED AT TRANSVERSE JOINT

WITHIN BASE COURSE

1996



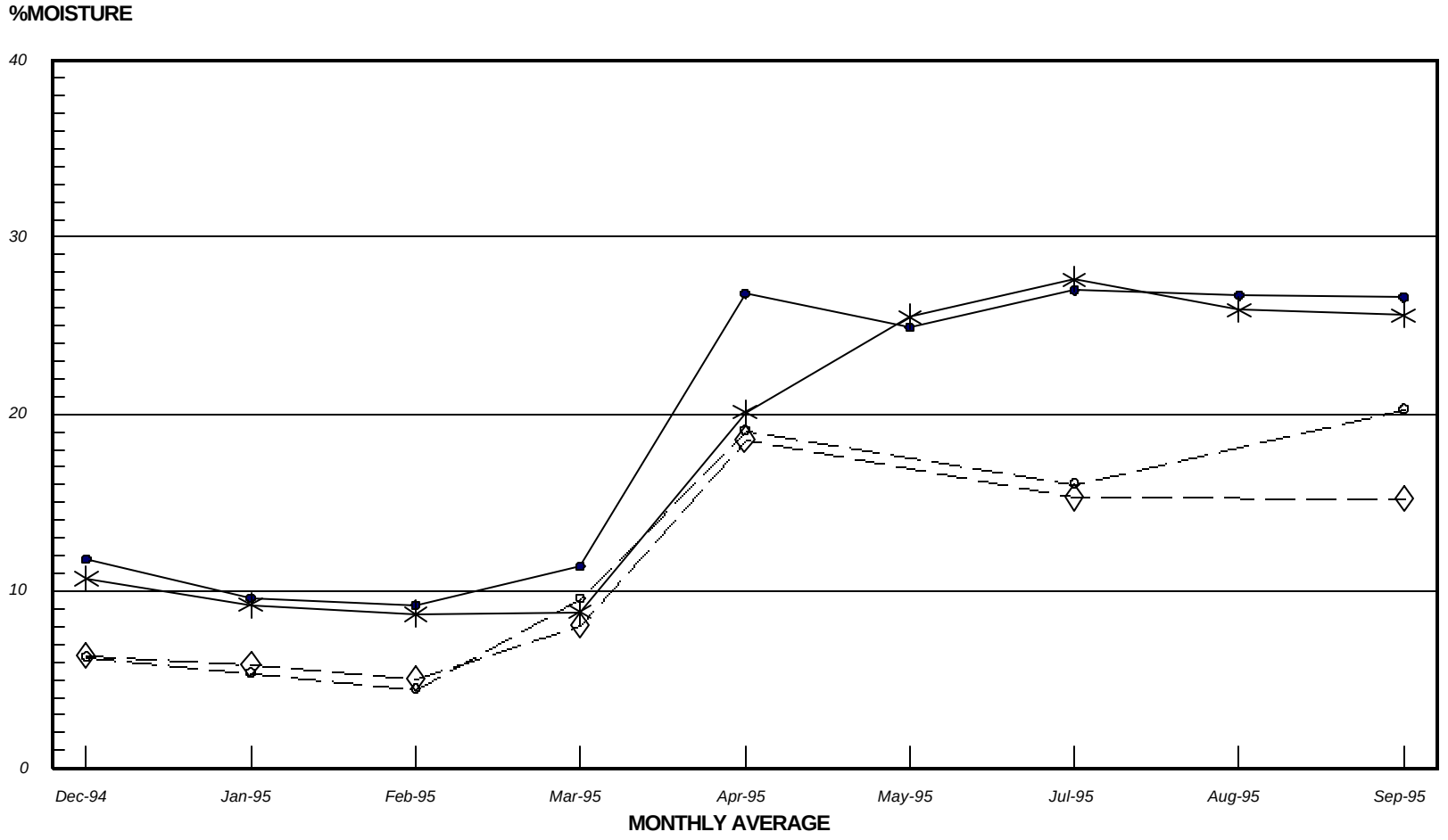
* Below Permeable Stabilized Base

Graph 2

SENSORS LOCATED AT MIDPANEL

WITHIN BASE COURSE

1995



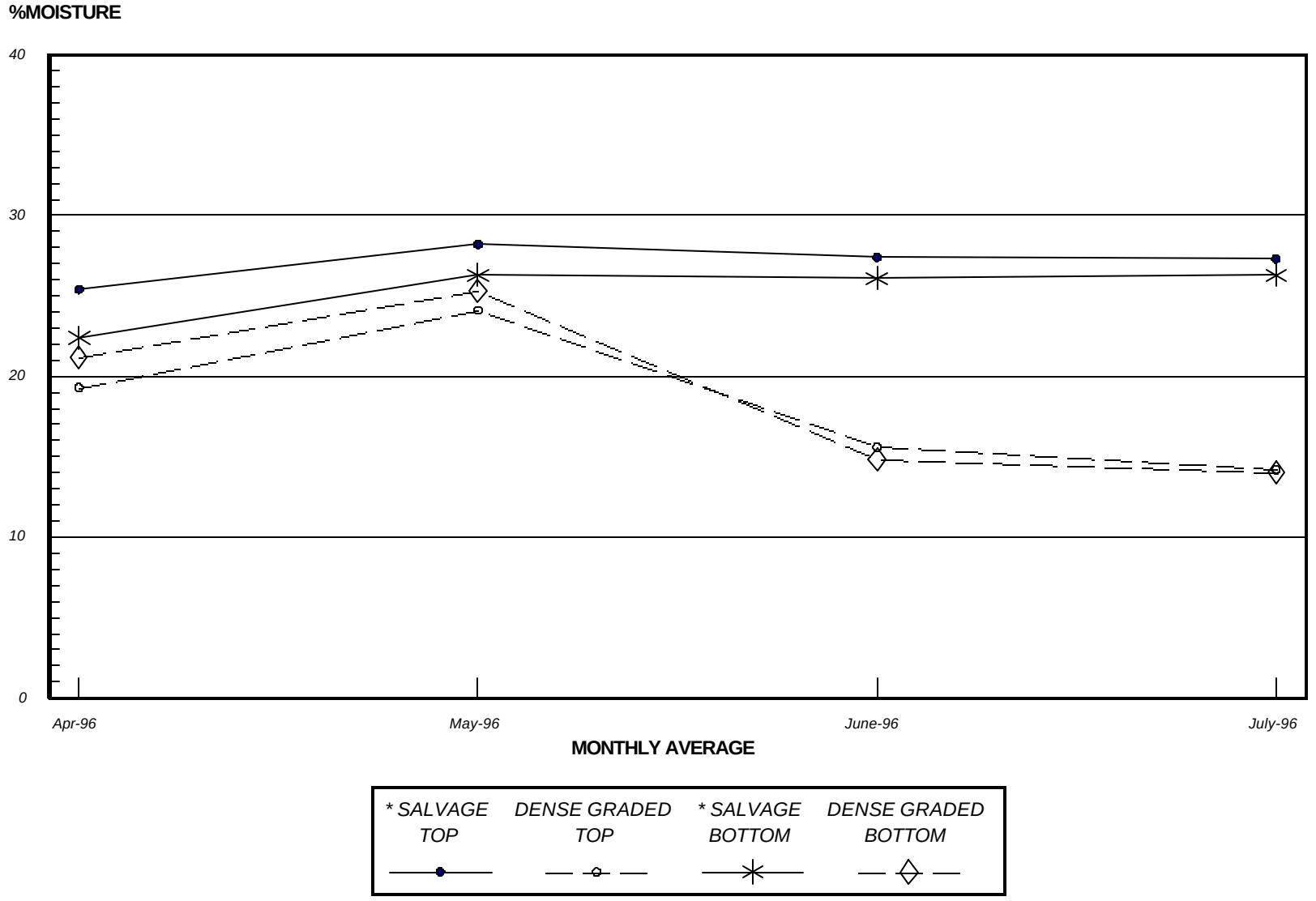
** Below Permeable Stabilized Base*

Graph 3

SENSORS LOCATED AT MIDPANEL

WITHIN BASE COURSE

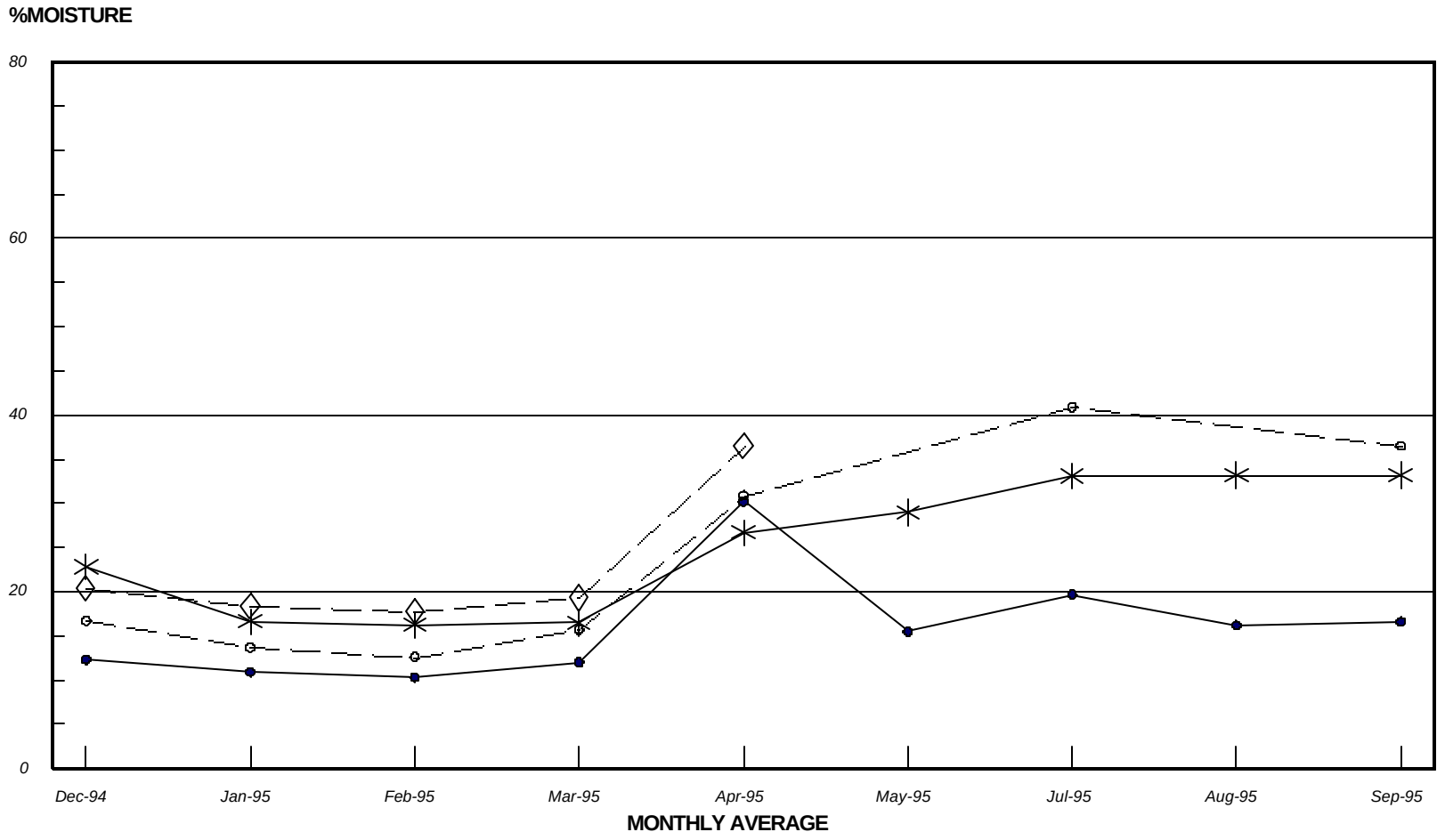
1996



Graph 4

SENSORS IN SUBGRADE

1995

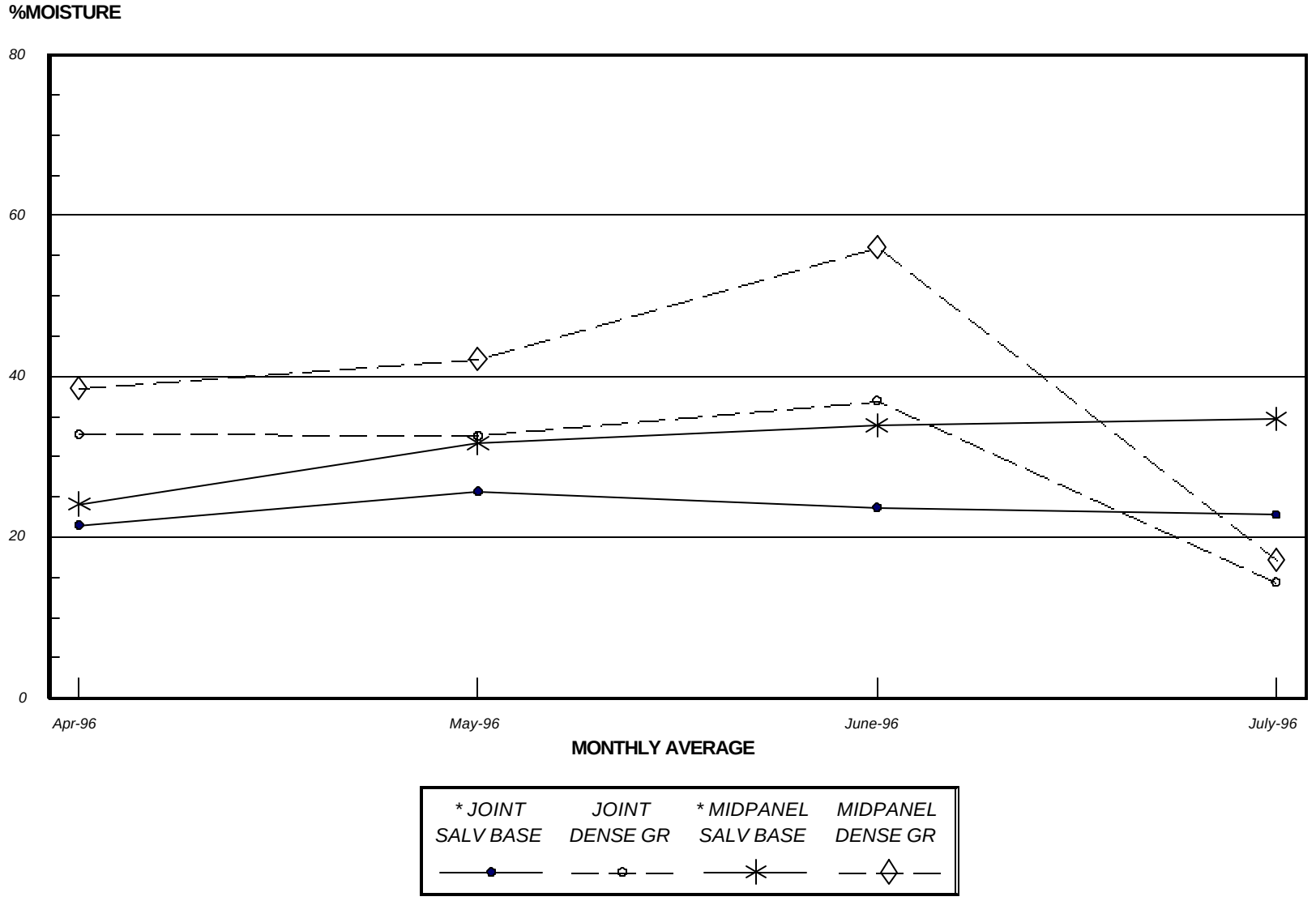


** Below Permeable Stabilized Base*

Graph 5

SENSORS IN SUBGRADE

1996



Graph 6

SUMMARY:

A comparison of sensor readings on Graphs 1 and 2 show that since construction, the top of the salvaged base course (Figure 5) averages 22% moisture at the joint location. The bottom of the salvaged base course (Figure 5) at the same location averages 35% moisture. Graphs 1 and 2 also show that the moisture content of the top of the dense graded base course (Figure 6) has an average of 27% moisture while the bottom of the dense course (Figure 6) has an average moisture content of 23%.

A comparison of sensor readings on Graphs 3 and 4, where the sensors are located at mid-panel, indicate that the top of the dense graded base course (Figure 7) has an average moisture of 18% at mid-panel and the bottom of the dense graded base course (Figure 7) has an average of 19% moisture. The graphs also show that the top of the salvage base course (Figure 8) has an average of 27% moisture while the bottom (Figure 8) has an average of 25% moisture.

Graphs 5 and 6 show the moisture contents in the subgrade below a transverse joint (Figure 5) to be 24 % below the salvage base and 31% below the dense graded base (Figure 8). The mid-panel moisture contents are 29% below the salvage base (Figure 6) and 38% below the dense graded base (Figure 7). A comparison of these moisture contents is shown in the following diagrams.

Figure 5

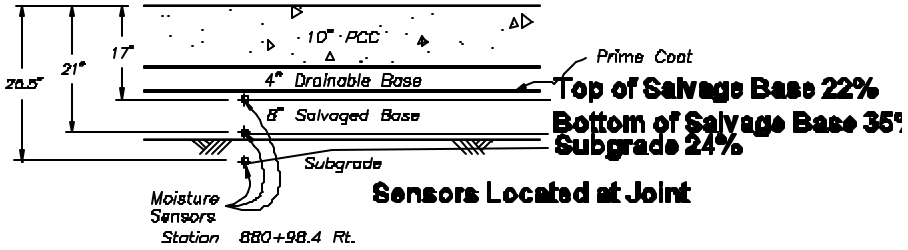


Figure 6

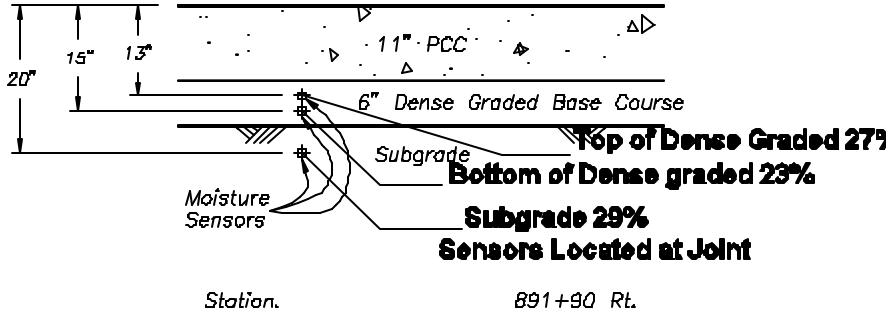


Figure 7

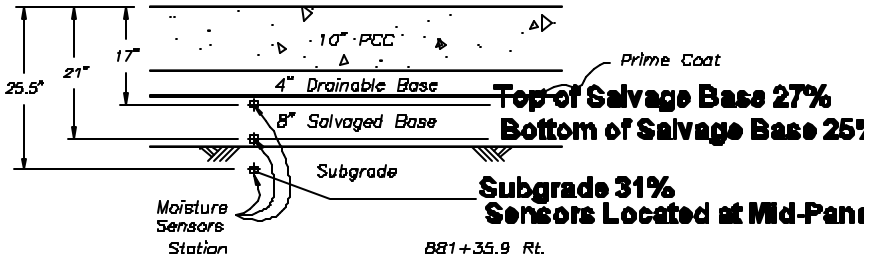
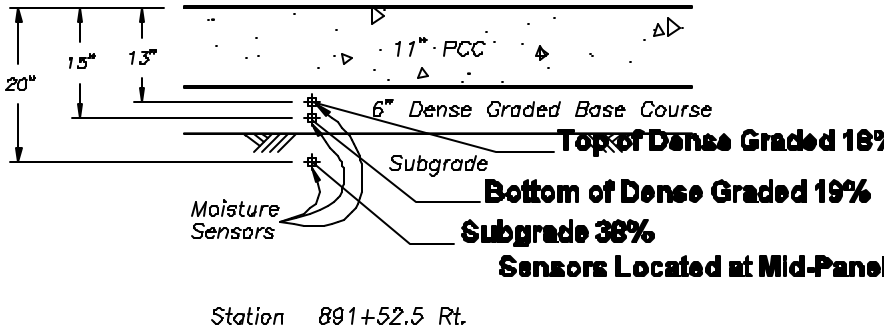


Figure 8



These results are inconclusive at this time. It appears that at joint locations the drainable base is not effective or is only marginally effective in reducing the moisture content in the base material. It is however effective in reducing the moisture content of the subgrade at the joint locations.

The mid-panel locations appear to show that the dense graded base is more effective than the drainable base, however the moisture content in the subgrade shows the drainable base to be more effective.

APPENDIX A

DESIGN DATA						
Traffic	Average Daily					Est Monthly
Current 1994	Pass. 3,455	Trucks 700	Total 4,155			450
Forecast 2014	Pass. 5,080	Trucks 1,050	Total 6,130			775
Minimum Sight Dist. for Stopping 625 FT	Design Speed 70 MPH					
Full Control of Access						
No Point of Access Other Than at Interchange Ramps						

JOB # ____

NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

IN CASS COUNTY

FEDERAL AID PROJECT IM-8-094(005)331

PCC RECYCLING & SPS-2 EXPERIMENTAL SECTIONS

FHWA REGION	STATE	PROJECT NO.	SHEET NO.
8	ND	IM-8-094(005)331	1

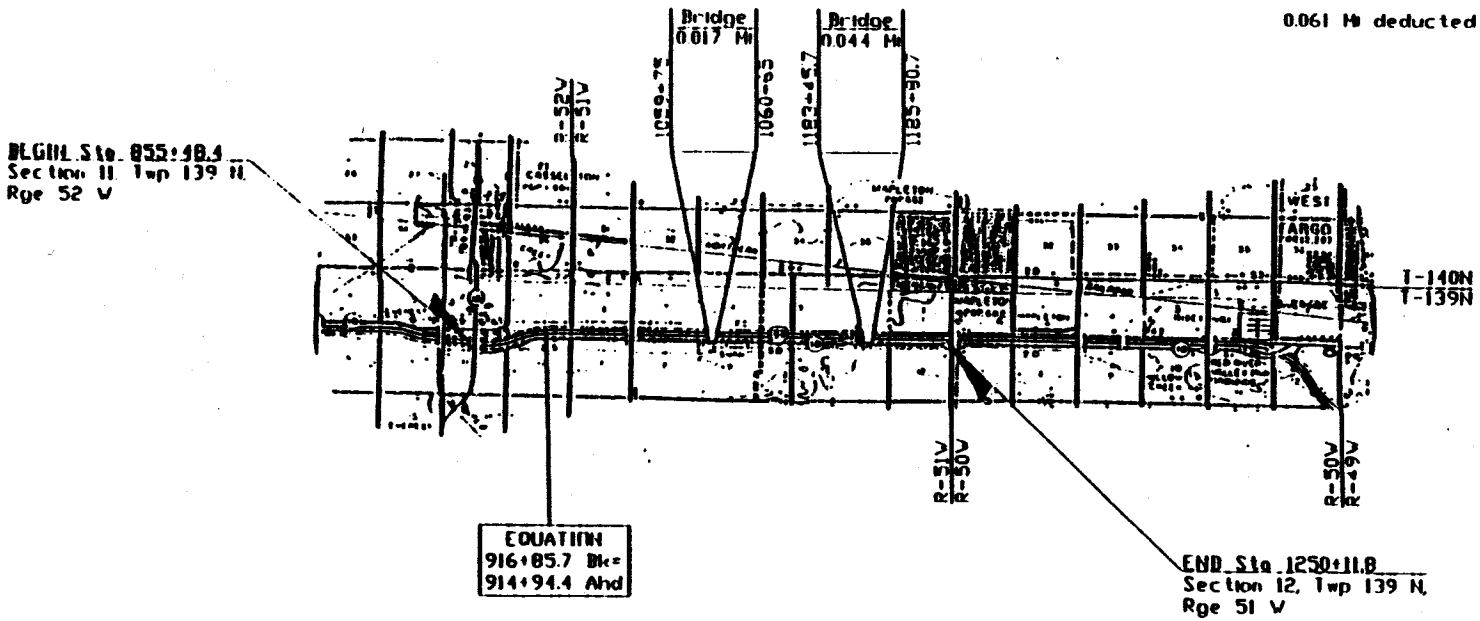
GOVERNING SPECIFICATIONS:

Standard Specifications adopted by the North Dakota Department of Transportation September 1992, Standard Drawings currently in effect, and other Contract Provisions submitted herein.

LENGTH OF PROJECT

Miles-Gross	Miles-Net
7.510	7.449

0.061 Mi deducted for bridges.



PAVING SECTION Brian Ross

URBAN SECTION

TRAFFIC SECTION Greg Stuhl

RURAL SECTION

RECOMMEND APPROVAL 2-1, 1994

DESIGN ENGINEER

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL HIGHWAY ADMINISTRATION

APPROVED

DIVISION ADMINISTRATOR DATE

APPROVED DATE 2-1-94

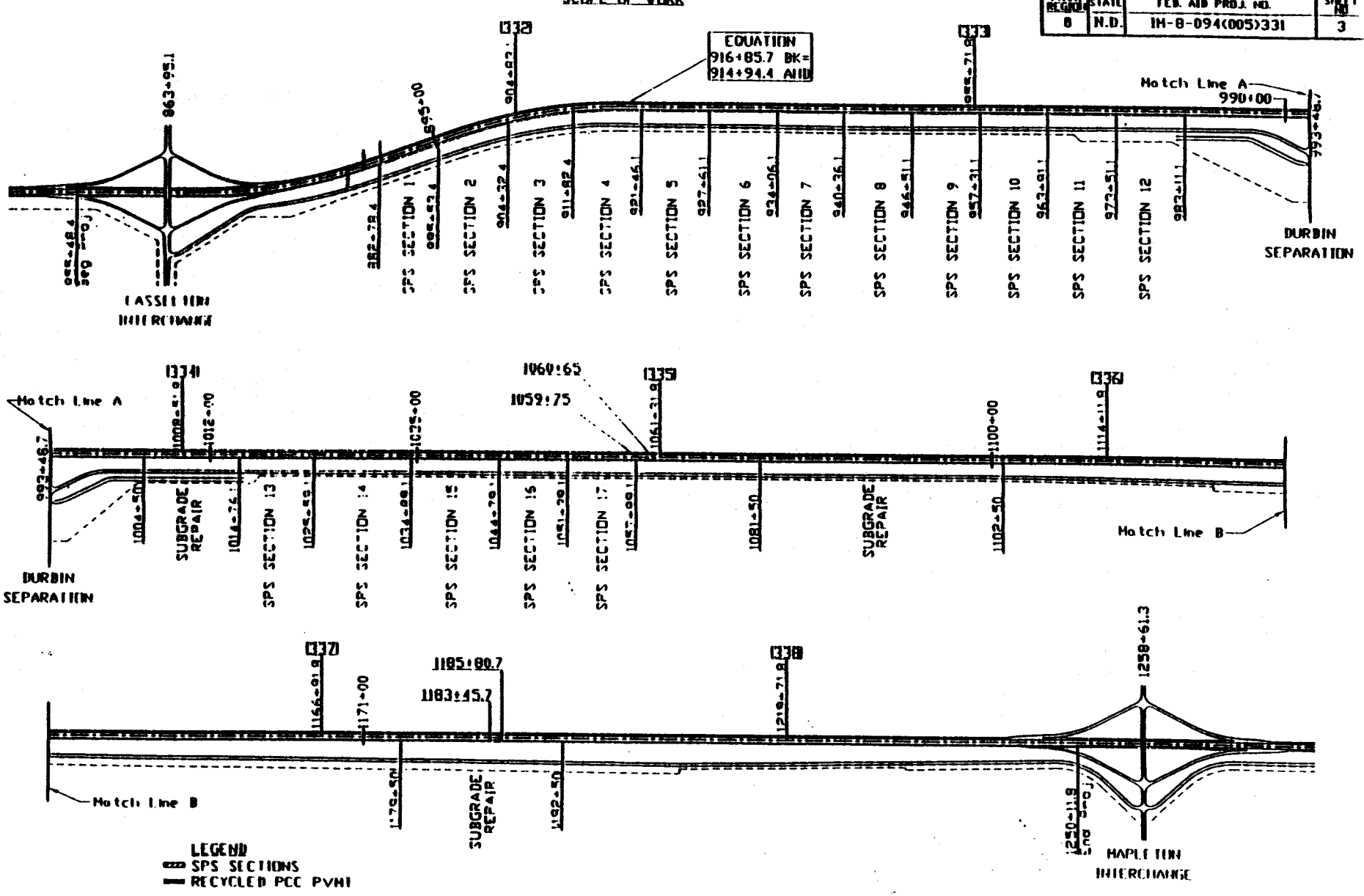
DIRECTOR OF HIGHWAYS AND ENGINEERING
NORTH DAKOTA DEPARTMENT OF TRANSPORTATION

RAY ZINK REGISTERED PROFESSIONAL ENGINEER

A-1

SCOPE OF WORK

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO
8	N.D.	IM-8-094(005)331	3



NOTES

990 P01 The contractor shall furnish the Department with a Pearpoint Color Flexiprobe System consisting of the following:

Quantity	ID #	Description
1 EA	HU2207101	Camera Control Unit
1 EA	HC0504901	5 Meter 16 Ft Link Cable
1 EA	HU1321201	T Piece
1 EA	HK1180001	Metal Coiler
1 EA	HC0505601	Rod 328'
1 EA	HI2662001	6W 44mm Lighthead
1 EA	HC2179801	Plastic Sleeve
1 EA	HC2174001	Camera Color
1 EA	PPIGS101	Spring Centering Device
1 EA	AHQRD400SL	Radio Sonde Receiver
1 EA	HI2662201	Lamp Replace PCB Kit
1 EA		4 Head VCR W/Audio & Video-In Capabilities
1 EA		Honda Generator 650 Watt

The specified system shall become the property of the Department. (NOTE: Northern Water Works Supply is the only licensed dealer of the Pearpoint flexible video system in North Dakota.)

The unit price bid for "Pearpoint Color Flexiprobe System" shall include all costs to provide this system.

990 P02 The contractor shall furnish and install a Moisture Sensor System consisting of the following:

Soilmoisture Equipment Corporation

Quantity	Product No.	Description
2	6050X1	Trase System 1
12	6005L2	Buriable Waveguide.(2 Meter Cable)
12	6006L20	Extension Cable (20 Meters)
2	6021C16	TDR Switching Board (16 Channel)
1	6022	Miltiplexer Control Board

Hennessy Products

Quantity	Product No.	Description
2	LS583017A13R	
2	231633	Shelf Kit
2	240627	Fan Thermostat
2	240625	300 Watt Heat Kit
2		Insulation Adder

The specified system shall become the property of the Department. The contractor shall install the Moisture Sensor System according to the manufacturer's recommendations. A representative from the Soilmoisture Equipment Corporation shall be present during installation of the equipment. The contact person is Richard White (phone number (805)964-3525.)

The contractor shall take the steps necessary to protect the sensors once they are in place. Damaged sensors shall be replaced at the contractor's expense.

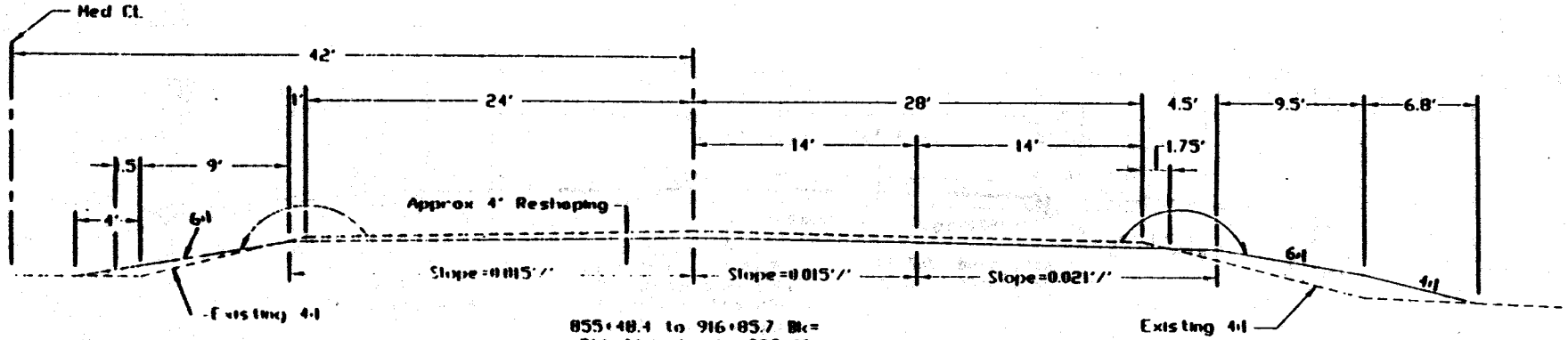
The cables running from the sensors to the cabinet shall be placed in 1 inch rigid conduit.

The contractor shall give 48 hours advance notice of installation of sensors to Cliff Kuntz of the NDDOT (phone number (701)221-6910.)

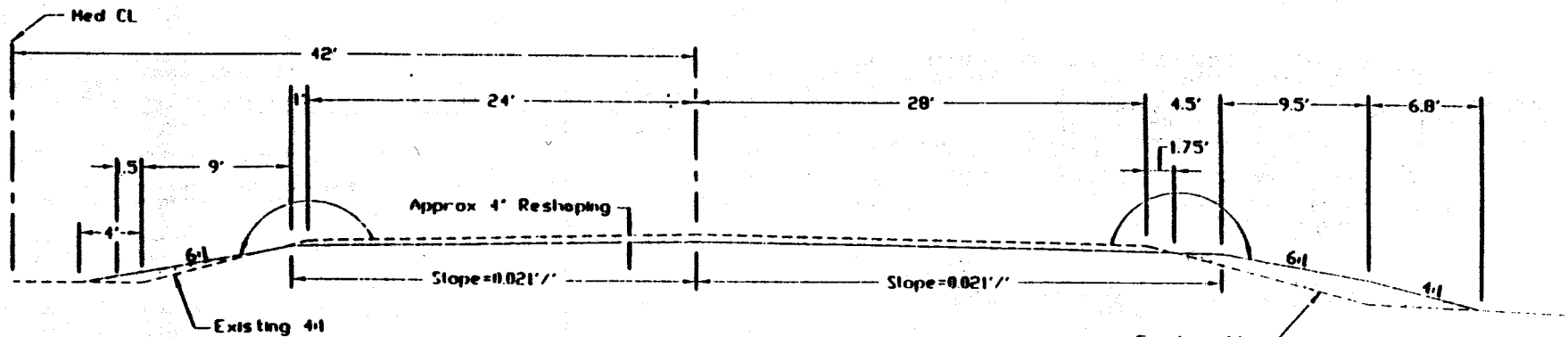
The unit price bid for "Moisture Sensor System" shall include all costs to provide and install this system.

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-8-094(005)331	18

RESHAPING ROADWAY



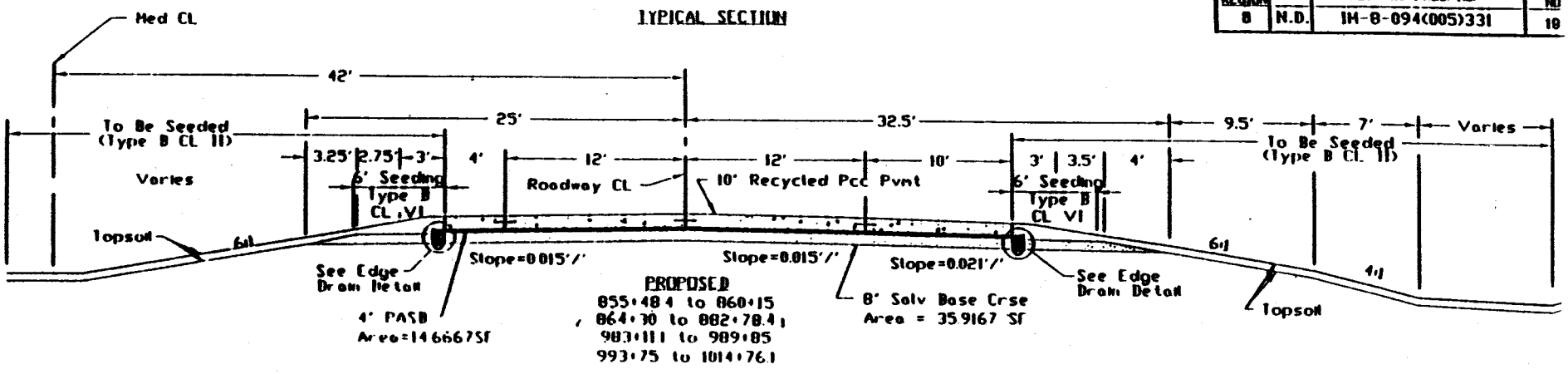
855+48.4 to 916+85.7 Bk=
914+94.4 Ahd to 987+00
1000+00 to 1059+55(End Appr Slab)



1060+85(End Appr Slab) to 1183+05.7(End Appr Slab)
1186+20.7(End Appr Slab) to 1250+11.8

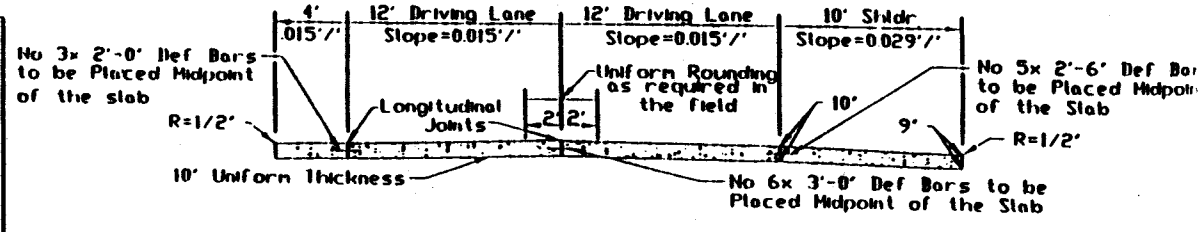
FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-8-094(005)331	19

TYPICAL SECTION



APPROXIMATE QUANTITIES

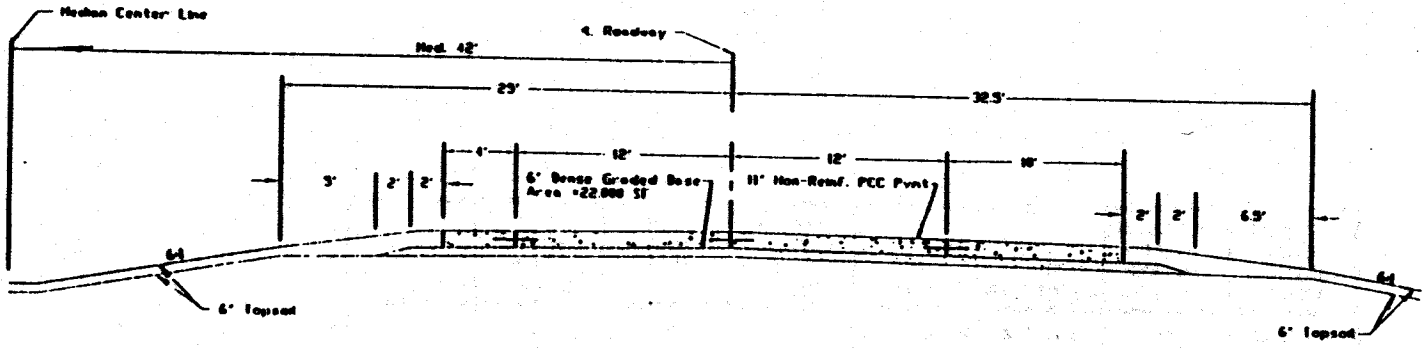
WIDTH	QUANTITY	UNIT	
	556	M Gal	40.2 M Gal Water for Dust Palliative and Subgrade Prep + 40 Gal/Ton of Salvaged Base Course
50.25'	12696	Ton	Salvaged Base Course
44'	4039	Ton	Permeable Asphalt Stabilized Base
	121	Ton	AC 20 Asphalt Cement
	10180	LF	Edge Drains
	546	LF	Outlet Pipe
30'	21491	SY	10" Non-Reinforced RPCC Pavement
	1412	Ton	Portland Cement
	332	Ton	Flyash
24'	8136	LF	Doweled Contraction Joint Assembly
30.5'	13052	LF	Contraction Joint Silicone Seal
44'	4977	Gal	MC-70 or 250 Liq Asph for Prime Coat @ .20 Gal/S.Y.



CROSS SECTION OF PCC PAVEMENT SLAB
(TANGENT)

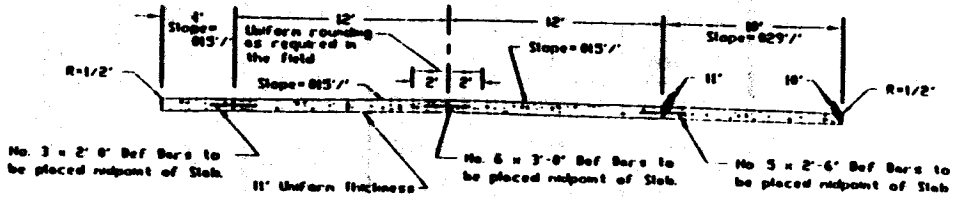
FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-094-8(089)330	22

DOWELED JOINTED PLAIN PCC PVMT
SOUTH ROADWAY
SECTION 1
Sta 882+784 to Sta 895+534



APPROXIMATE QUANTITIES

WIDTH	QUANTITY	UNIT	
	SY	M Gal	121 M Gal Water for Dust Palliative and Subgrade Prep. + 20 Gal/Ton of Dense Graded Base Course
42'	1958	Ton	Dense Graded Base Course
30'	5303	SY	11" Non-Reinforced PCC Pavement - CLASS AE
30.5'	3272	LF	Contraction Joint Silicone Seal
24'	2948	LF	Doweled Contraction Joint Assembly



CROSS SECTION OF PCC PAVEMENT SLAB
(TANGENT)

A-6

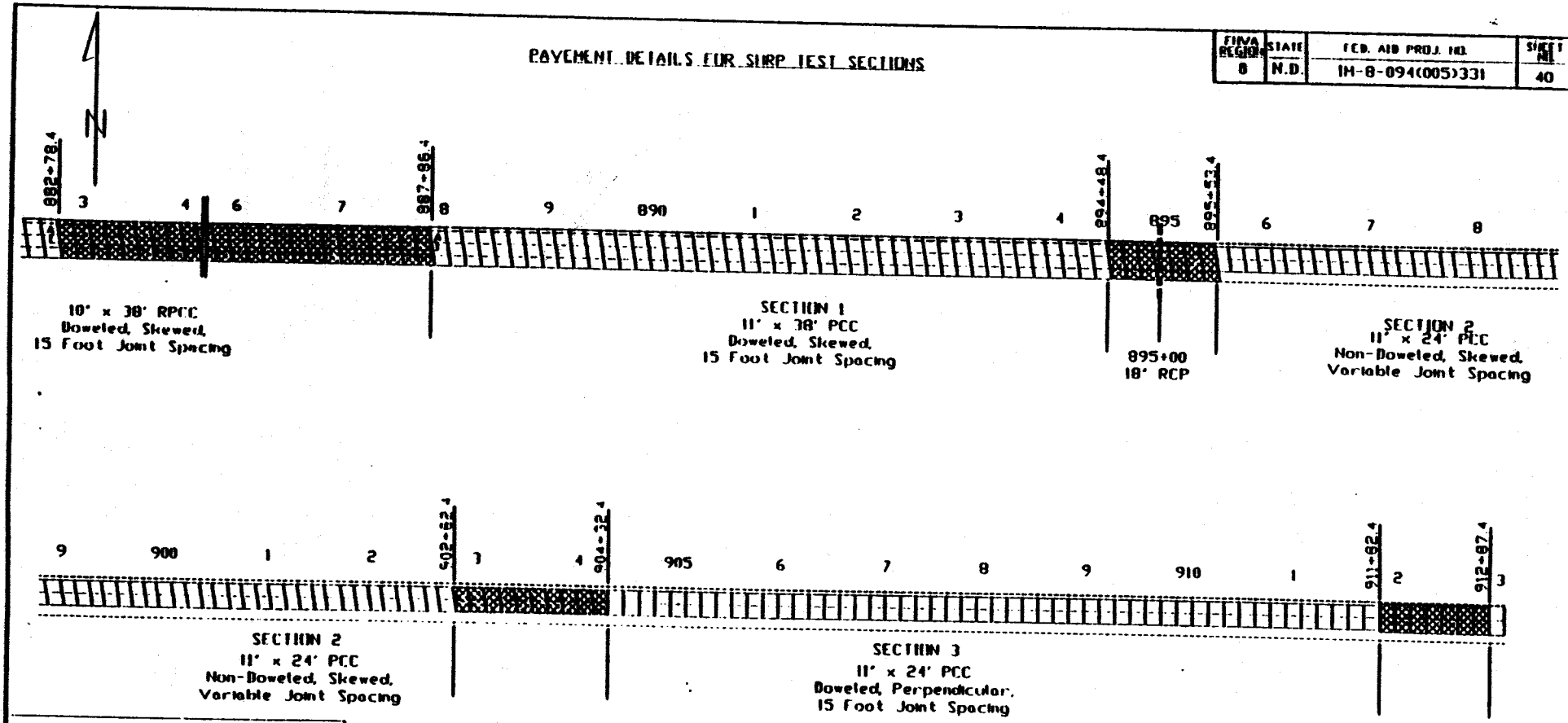
TABLE OF VARIATION FOR SECTION 1 THRU SECTION 17

TYPICAL SECTION	PCC PVMT DEPTH (INCHES)	PCC PVMT WIDTH (FEET)	14 DAY FLEXURAL STRENGTH (PSI)	BASE TYPE	JOINT ORIENTATION	TRANSVERSE JOINT SPACING (FEET)	TYPE OF LOAD TRANSFER DEVICE
1	11	38	*	CL 5 AGGR	SKEWED	15	DOWELS
2	11	24	550	CL 5 AGGR	SKEWED	VARIABLE	NONE
3	11	24	550	CL 5 AGGR	90°	15	DOWELS
4	11	28	900	CL 5 AGGR	90°	15	DOWELS
5	8	24	900	CL 5 AGGR	90°	15	DOWELS
6	8	28	550	CL 5 AGGR	90°	15	DOWELS
7	8	28	550	LCB	90°	15	DOWELS
8	8	24	900	LCB	90°	15	DOWELS
9	11	28	900	LCB	90°	15	DOWELS
10	11	28	550	LCB	SKEWED	VARIABLE	NONE
11	11	24	550	LCB	90°	15	DOWELS
12	11	24	550	PASB	90°	15	DOWELS
13	11	24	550	PASB	SKEWED	VARIABLE	NONE
14	11	38	*	PASB	SKEWED	15	NONE
15	11	28	900	PASB	90°	15	DOWELS
16	8	28	550	PASB	90°	15	DOWELS
17	8	24	900	PASB	90°	15	DOWELS

* Class AE as per NDDOT Specifications.

PAVEMENT DETAILS FOR SURF TEST SECTIONS

FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-8-094(005)331	40



LEGEND

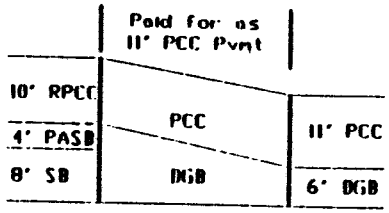
PCC- Portland Cement Concrete
PASB- Perm Asph Stabilized Base
LCB- Lean Concrete Base
DGB- Dense Graded Base
RPCC- Recycled PCC
SB- Salvaged Base

--- Tied Longitudinal Joint

----- Edge of Hot Bit Pvmt

—— Edge of PCC Slab

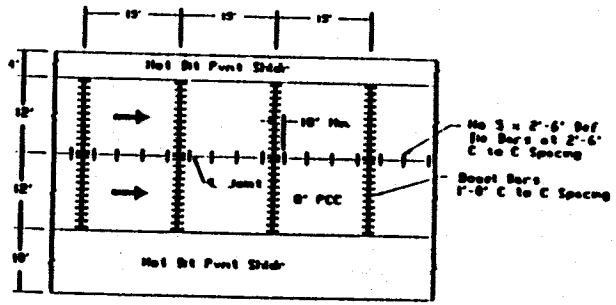
Transition



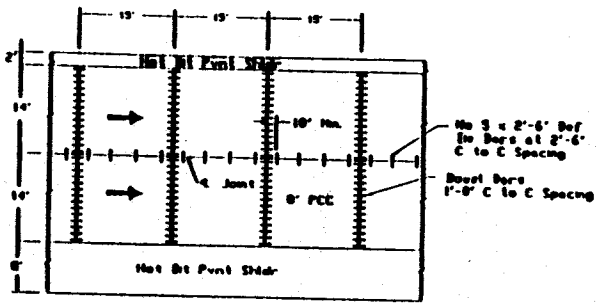
SECT A-A

JOINT DETAILS

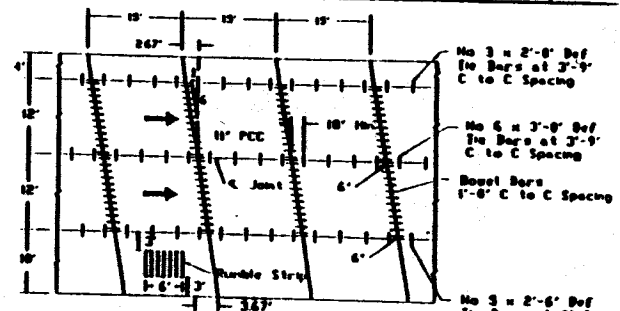
FHWA REGION	STATE	FED. AID PROJ. NO.	SHEET NO.
8	N.D.	IM-0-094(083)336	48



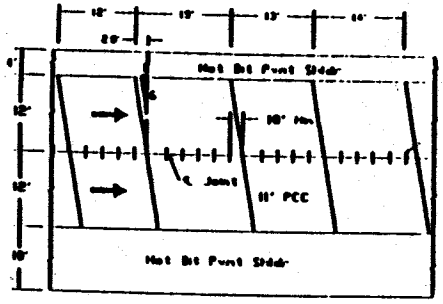
PERPENDICULAR TRANSVERSE JOINTS
Sections 5,8,& 17



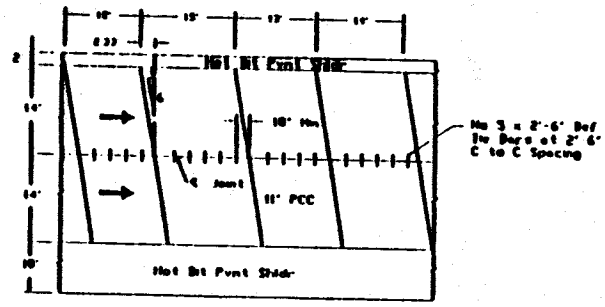
PERPENDICULAR TRANSVERSE JOINTS
Sections 6,7,& 16



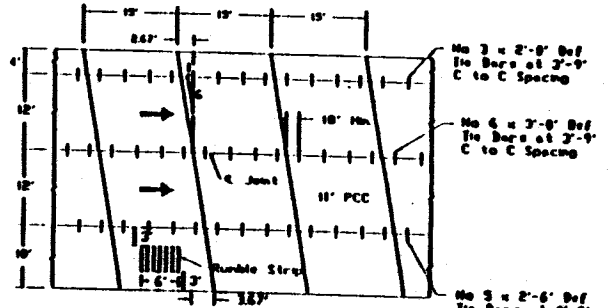
SKEWED TRANSVERSE JOINTS
Section 1



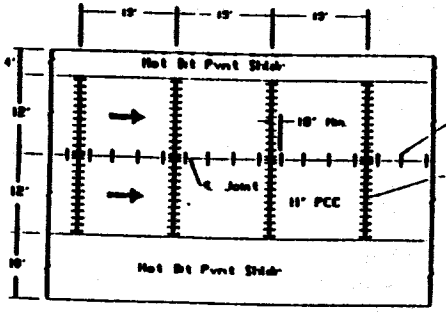
SKEWED TRANSVERSE JOINTS
Sections 2 & 13



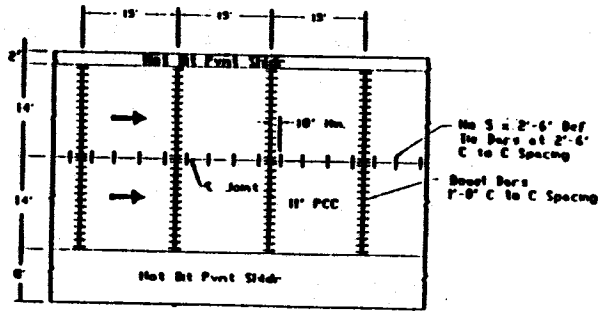
SKEWED TRANSVERSE JOINTS
Section 10



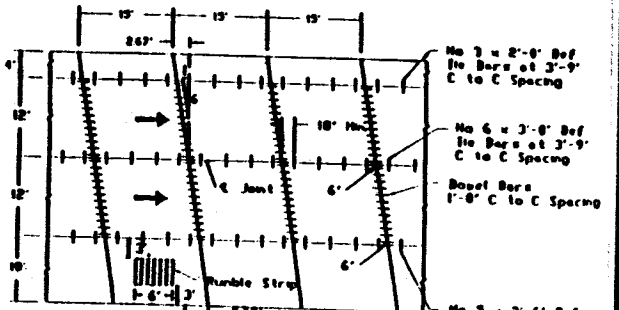
SKEWED TRANSVERSE JOINTS
Section 14



PERPENDICULAR TRANSVERSE JOINTS
Sections 3,11,& 12



PERPENDICULAR TRANSVERSE JOINTS
Sections 4,9,& 15



SKEWED TRANSVERSE JOINTS
10" Recycled PCC